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Fruit, vegetable and brewers' waste

Table 6.17 Nutrient analysis (%) of citrus sludge.
 (From (1) Eldred, Damron and Harms, 1976; (2)
 Hackler, Newman and Johnson, 1957)

	1	2	
Moisture	6.3	Methionine	0.5
Crude protein	38.6	Cystine	0.2
ME (MJ/kg)	7.4	Lysine	1.3
Crude fibre	12.6		
Calcium	1.5		
Phosphorus	1.6		

determination of metabolizable energy (7.4 MJ/kg) was based on an estimation value for comparable materials. Hackler, Newmann and Johnson (1957) reported values for the amino acids methionine 0.50%, cystine 0.20%, and lysine 1.3% for sewage sludge. Eldred, Damron and Harms (1976) used these for amino acids in sewage sludge for the calculation in their experiment (Table 6.17).

(c) Citrus molasses

Citrus molasses is a liquid obtained from cured citrus waste. It contains 10–15% of soluble solids of which 50–70% are sugars. This material contributes more than 50% of the total weight of cannery refuse available to the feed mill. A typical analysis of citrus molasses is as follows: concentration 72 °Brix, pH 5, viscosity 2000 centipoises, nitrogen-free extract 62%, total sugars 45%, moisture 29%, and crude protein 4.1%. Table 6.18 shows its complete composition (Hendrickson and Kesterson, 1951).

Citrus molasses resembles cane molasses and is used in the feeding of dairy cattle. Its extreme bitterness makes it unsuitable for human consumption unless treated for removal of naringin, but the bitterness does not appear to affect its use in animal feeding (Burdick and Maurer, 1950). Its use in poultry nutrition is not known but it has been suggested that it could be used as a binding material during pelleting in the place of cane molasses.

6.3.4 Feeding citrus waste

(a) Citrus pulp

Broilers

Ewing (1963) reported that chicks fed on citrus pulp showed a decreased growth rate, compared with controls, during the first 4 weeks. The

Table 6.18 Chemical composition of citrus molasses. (From Hendrickson and Kesterson, 1951)

Constituent	%
Nitrogen-free extract	62.000
Total sugars	45.000
Moisture	29.000
Reducing sugars	23.500
Sucrose	20.500
Carbonate ash	4.700
Acid, as anhydrous citric	4.500
Nitrogen × 6.25	4.100
Glucoside	3.000
Pentosans	1.600
Pectin	1.000
Fat	0.200
Volatile acids	0.040
Potassium	1.100
Calcium	0.800
Sodium	0.300
Magnesium	0.100
Iron	0.080
Chlorine	0.070
Phosphorus	0.070
Silica	0.010
Manganese	0.008
Copper	0.003

inclusion of citrus meal up to 20% in chick diets resulted in a very high mortality, while the 10% inclusion level led to a higher feed consumption per unit of gain and no extra mortality was observed. Schaible (1970) found that citrus seed pulp caused a high mortality during the first 3 weeks and caused enlarged gall bladders, mottled liver and congestion of the intestinal tract owing to the presence of limonin.

Buriel, Criollo and Rivera (1976) carried out trials in which high levels of citrus pulp were used (0, 20, 30 and 40% in broiler diets for starter and finisher). The analysis of variance and orthogonal comparisons showed highly significant differences among the means of the variables studied: body weight, feed consumption and conversion (Table 6.19). They concluded that citrus pulp meal cannot be used at levels of 20% or higher in rations for broilers. Their results do not give a real picture of the effect of dried citrus pulp in levels lower than 20%, which are levels that are considered to be of great importance for such a product in poultry nutrition.

El Moghazy and El Boushy (1982b) investigated lower levels of dried citrus pulp in diets for broilers. Their diets were calculated on a base of 60% yellow maize and 19% soybean oil meal. Besides the control diet,

Table 6.19 Average body weight, feed consumption and conversion of broilers fed various levels of dried citrus pulp in comparison with a control diet. (From Buriel, Criollo and Rivera, 1976)

Treatment	Average weight (g/chick)		Feed consumption (g/chick)		Feed conversion	
	0-4 weeks	0-8 weeks	0-4 weeks	0-8 weeks	0-4 weeks	0-8 weeks
Control	661 ^a	1669 ^a	1154 ^a	3036 ^a	1.6 ^a	1.8 ^a
20%	571 ^b	1374 ^b	1054 ^a	3156 ^b	1.8 ^a	2.3 ^b
30%	459 ^c	1293 ^b	1365 ^b	3374 ^c	3.0 ^b	2.6 ^b
40%	408 ^d	1099 ^c	1541 ^c	3396 ^c	3.8 ^b	3.1 ^b

^{a,b,c,d} Means within a column with the same superscript are not significantly different at $P < 0.01$.

Table 6.20 Composition of the experimental mash diets. (From El Moghazy and El Boushy, 1982a)

Ingredients (%)	Control	Citrus pulp				
		2.5%	5.0%	7.5%	10.0%	12.5%
Yellow corn	60.30	57.04	53.70	50.44	47.20	44.44
Soybean meal (48.8%)	19.30	19.02	18.79	18.48	18.17	17.76
Rice polishing	2.75	2.75	2.75	2.75	2.75	2.75
Citrus pulp	0.00	2.50	5.00	7.50	10.00	12.50
Meat meal (58%)	7.60	8.05	8.50	9.00	9.50	10.00
Herring meal (72%)	3.00	3.00	3.00	3.00	3.00	3.00
Animal fat	3.70	4.50	5.32	6.10	6.88	7.50
Dicalcium phosphate (18.2% P; 26% Ca)	0.90	0.84	0.78	0.71	0.64	0.57
Limestone	0.99	0.83	0.69	0.54	0.39	0.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin, minerals premix mixture	1.00	1.00	1.00	1.00	1.00	1.00
Methionine (99%)	0.12	0.13	0.14	0.15	0.15	0.16
Lysine-HCl (78%)	0.04	0.04	0.03	0.03	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00	100.00

the experimental diets contained citrus pulp at 2.5, 5, 7.5, 10 or 12.5% added at the expense mainly of maize. Crude fibre content was 2.03% for the basal diet and 2.28–3.72% with increasing citrus pulp inclusion. All diets were isonitrogenous (22% crude protein) and isocaloric (13.4 MJ/kg metabolizable energy). Limiting amino acids were constant by the addition of synthetic amino acids to cover the requirements. The digestible levels of methionine and lysine were 0.46% and 1.03%,

Table 6.21 Calculated contents of the diets with different levels of citrus pulp. (From El Moghazy and El Boushy, 1982a)

	Control		Citrus pulp inclusion				
			2.5%	5.0%	7.5%	10.0%	12.5%
Crude protein	22.00	22.00	22.00	22.00	22.00	22.00	22.00
ME (MJ/kg)	13.40	13.40	13.40	13.40	13.40	13.40	13.40
Ether extract	8.12	8.91	9.73	10.52	11.32	11.96	
Crude fibre	2.03	2.28	2.52	2.77	3.01	3.27	
Ash	6.08	6.06	6.08	6.07	6.06	5.84	
Calcium	1.20	1.19	1.20	1.20	1.20	1.11	
Total phosphorus	0.79	0.78	0.78	0.77	0.77	0.76	
Available phosphorus	0.55	0.55	0.55	0.55	0.55	0.55	
Linoleic acid	1.79	1.80	1.82	1.83	1.85	1.85	
Total methionine	0.52	0.52	0.52	0.53	0.53	0.54	
Digestible methionine	0.46	0.46	0.46	0.46	0.47	0.47	
Total (meth. + cyst.)	0.86	0.86	0.86	0.86	0.86	0.86	
Digestible (meth. + cyst.)	0.72	0.71	0.71	0.71	0.71	0.70	
Total lysine	1.25	1.25	1.25	1.25	1.25	1.25	
Digestible lysine	1.03	1.03	1.03	1.02	1.02	1.01	

Table 6.22 Average body weight, feed consumption and conversion of male broilers fed on various levels of dried citrus pulp in comparison with a basal ration. (From El Moghazy and El Boushy, 1982a)

Treatment	Body weight (g/chick)		Feed consumption (g/chick)		Feed conversion	
	0-4 weeks	0-7 weeks	0-4 weeks	0-7 weeks	0-4 weeks	0-7 weeks
Control	851 ^b	2060	1320	3910	1.63 ^a	1.94 ^a
Citrus pulp						
2.5	830 ^{a,b}	1990	1320	3820	1.67 ^{a,b}	1.96 ^a
5	856 ^b	2040	1350	3910	1.66 ^a	1.96 ^a
7.5	817 ^{a,b}	2040	1300	3940	1.67 ^{a,b}	1.97 ^a
10	814 ^{a,b}	2000	1330	3907	1.71 ^{b,c}	1.99 ^{a,b}
12.5	792 ^a	2000	1310	4000	1.74 ^c	2.04 ^b

^{a,b,c} Means within a column with another superscript are significantly different ($P < 0.05$) by Duncan's multiple range test.

respectively (Tables 6.20 and 6.21). Adding citrus pulp in levels higher than 7.5% depressed body weight at 4 weeks but less at 7 weeks of age. Feed intake was decreased at 4 weeks and increased at 7 weeks of age, but not significantly. With citrus pulp at a 12.5% level of inclusion, feed conversion was low in the control and increased with increasing citrus pulp levels (Table 6.22). This effect was paralleled by an increasing crude fibre and limonin content in the diet (Table 6.22).

Table 6.23 Various calculations of crude fibre and limonin consumption for total mixture and dried citrus pulp. (From El Moghazy and El Boushy, 1982a)

Item	Age (weeks)	Control	Citrus pulp inclusion				
			2.5%	5%	7.5%	10%	12.5%
Crude fibre consumed from dried citrus pulp (g)	4	0.0	4.3	8.8	12.7	16.9	21.3
	7	0.0	12.4	25.4	38.4	50.8	65.0
Crude fibre consumed from total mixture (g)	4	26.8	30.1	34.0	36.0	39.1	42.8
	7	79.4	87.1	98.5	109.1	117.6	130.8
Limonin consumed from dried citrus pulp (mg)	4	0.0	2.9	5.9	8.5	11.6	14.3
	7	0.0	8.3	17.0	25.7	34.0	43.5

suggested that fibre content of the pulp allowed a rapid passage of ingesta and poorer digestion, and limonin may cause intestinal irritation and cause poor absorption of the nutrients. The researchers concluded that dried citrus pulp was a reasonable feedstuff for broilers at an inclusion level of 7.5% of the diet.

Layers

Karunajeewa (1978) reported from his studies on the effect of dried citrus pulp meal on egg yolk colour and performance of cross-bred layers. During his experiments diets were used without xanthophyll pigments to produce depleted coloured egg yolks. He fed those layers a control diet and two experimental diets with 5% citrus pulp with or without inclusion of 1 mg/kg canthaxanthin. He concluded that egg production, feed intake and conversion were not affected by the inclusion of 5% citrus pulp. Dried citrus pulp did not affect yolk pigmentation in the presence or absence of canthaxanthin.

Velloso (1985) included up to 10% orange pulp in diets for laying pullets to replace maize. Results showed no significant differences concerning growth, sexual maturity or mean egg weight up to 50% laying capacity. He concluded that the inclusion of 5% dehydrated and pelleted orange pulp could partly substitute maize without affecting laying or growth.

Yang and Choung (1985) used dried citrus peels at levels of 5, 10 or 15% to replace wheat bran in a basal diet containing 60% maize, 10% wheat bran, 16% soybean meal and 3.5% fish meal. The diet with 15% dried citrus peel decreased feed efficiency and gave darker egg yolks. There were no significant differences between the groups in weight gain. They concluded that the optimum inclusion of dried citrus peel in the diet is 10%.

Table 6.24 Performance of broilers fed diets containing various levels of citrus sludge (8 weeks). (From Eldred, Damron and Harms, 1976)

Sludge (%)	Body weight (g)	Feed consumption (g)	Feed conversion (g feed/g body weight)
0.0	1750	3696 ^{a,b}	2.16
2.5	1772	3528 ^a	2.08
5.0	1800	3752 ^b	2.16
10.0	1732	3808 ^b	2.25

^{a,b} Means without common letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.

(b) Citrus sludge

Broilers

Eldred, Damron and Harms (1976) reported that citrus sludge could be used as a supplement in broiler diets. Weight gains from diets containing 7.5% or less of this sludge were acceptable, while 10% or more decreased weight gain. The cause of the depression may be due to a deleterious factor known as limonin. They also used chick experimental diets containing 0, 2.5, 5, 10, 15 and 20% dried citrus sludge and 20% sludge plus additional methionine and lysine. Their data indicate that levels between 5 and 10% sludge could be included in diets of growing chicks up to 28 days without adversely affecting growth or other performance criteria. In another experiment broiler chicks from 1 day old were given a diet with 0, 2.5, 5 or 10% citrus sludge at the expense of maize and soybean meal. There was no significant difference in body weight between groups at 8 weeks old. Feed consumption and conversion values were also not significantly influenced by treatment (Table 6.24). These data indicate that a level of sludge between 5 and 10% can be used in the diets of broilers.

Angalet *et al.* (1976) evaluated citrus sludge as a poultry feed ingredient and its effect on the meat quality and flavour of broilers. In their trials the broilers were fed diets containing either 0, 2.5, 5.0 or 10.0% citrus sludge. At the end of 8 weeks they noticed no significant ($P < 0.05$) differences among levels of citrus sludge in the diet and carcass characteristics such as carcass weight, percentage cooking loss, shear force of meat or sensory evaluation (palatability scores).

Layers

Eldred, Damron and Harms (1976) evaluated the activated citrus sludge in feeding trials with laying hens. They used diets containing 0, 2.5, 5.0, 7.5 or 20% citrus sludge (Table 6.25). Inclusion of up to 7.5% sludge in the diet did not significantly affect hen-day egg production,

Table 6.25 Performance of laying hens fed diets containing various levels of citrus activated sludge (6 months). (From Eldred, Damron and Harms, 1976)

Treatment (% sludge)	Av. egg production (%)	Egg wt (g)	Feed/bird/ day (g)	Feed/dozen eggs (kg)	Specific gravity	Haugh units
0.0	69.6 ^a	62.9 ^a	113 ^a	2.00 ^a	1.0792	64.3 ^a
2.5	68.3 ^a	63.4 ^a	109 ^a	1.98 ^a	1.0801	67.4 ^{a,b}
5.0	67.0 ^a	63.6 ^a	114 ^a	2.13 ^a	1.0787	69.4 ^b
7.5	69.2 ^a	63.3 ^a	112 ^a	2.01 ^a	1.0780	68.9 ^b
20.0	42.1 ^b	59.0 ^b	92 ^b	2.86 ^b	1.0781	82.0 ^c

^{a,b,c} Means without common letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.

egg weight, daily feed intake or feed efficiency. No significant differences were found in the specific gravity of the eggs due to the treatment. Haugh unit scores were numerically increased as the level of sludge in the diet increased up to 7.5%. Mortality was not affected by the inclusion of up to 20% citrus sludge in the diet.

Angalet *et al.* (1976) evaluated activated citrus sludge as a feedstuff for layers and the characteristics of their eggs such as yolk colour and egg flavour. Eggs were collected from layers fed diets prepared with citrus sludge at levels of 0, 2.5, 5.0, 7.5 or 20.0% and were examined for differences in yolk colour and development of off-flavour. Colour differences ($P < 0.05$) were observed by reflectance colorimetry and the taste panel. The colour of the yolks increased (was more orange) as the dietary citrus sludge levels were increased. No significant flavour differences were detected by the taste panel for either the yolk or albumen.

6.4 POTATO RESIDUES

6.4.1 Introduction

Potato belongs to the tubers of the nightshade family and is the only important species of the family Solanaceae yielding edible tubers. Potato is known as *Solanum tuberosum* L. A great number of varieties has been produced by breeding and cultivation, the main points of difference being size, form, depth of eyes, colour, starch content, productiveness and resistance to disease.

The potato is a tuber, an abruptly thickened underground stem, closely resembling the aerial stem of the plant. Figure 6.7 shows the organization of the principal internal tissues of the mature potato